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CLIPPING as a Method of Harvesting GUAYULE for Rubber

By Albert S. Hunter,
Lauren M. Burtch,
and C. H. McDowell

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Clipping as a Method of Harvesting Guayule for Rubber

By Albert S. Hunter, formerly *senior agronomist*, Lauren M. Burtch, formerly *research agronomist*, and C. H. McDowell, formerly *assistant agronomist, Agricultural Research Service*[1]

The customary method of harvesting guayule (*Parthenium argentatum* A. Gray) is to dig it, taking not only the whole top but also the upper 6 or 8 inches of the root system. A fourth to a third of the total rubber obtained by this method is contained in the roots. If another crop of guayule is to be grown on the same land, a new stand must be established. This is a major item of production expense. The one method of reestablishment that has been used in the United States is to grow and transplant nursery stock. Planting stock is grown by seeding in irrigated nurseries in the spring, and the seedlings are topped back, dug, and transplanted in field rows the following winter or spring. Tingey,[2] in 1943, developed a method of seeding guayule in the field, but this method requires maintenance of high moisture levels at the soil surface during germination (guayule seed are planted one-fourth to one-half inch deep) and is uncertain on nonirrigated lands.

In 1911 Lloyd [3] suggested an alternative method of harvesting only the tops of guayule plants, leaving the roots to generate a new crop. This harvesting procedure, which in this paper is called clipping, is comparable to that ordinarily used with perennial forage crops such as alfalfa. Prior to 1931 the Intercontinental Rubber Co. experimented in harvesting guayule by clipping, but the company did not adopt the method in its operations. Curtis [4] began clipping studies on guayule under the Emergency Rubber Project of the Department of Agriculture in 1944. Curtailment of Federal funds for guayule research limited his investigations to the brief period of 18 months. He found that tops clipped 1½ inches above the ground contained two-thirds of the rubber in the whole plant [5] and that such tops were

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[1] Dr. Hunter is now professor of soil technology, The Pennsylvania State University, University Park, Pa.; Mr. Burtch is now agronomist, Spreckels Sugar Co., Woodland, Calif.; Mr. McDowell has retired. Thanks are expressed to Marion F. Slattery for rubber determinations and to Eleanor H. Taylor for statistical analyses.

[2] Tingey, D. C. the comparative value of dry, pregerminated, and threshed guayule seed in direct field seeding. July 1943. [Unpublished report on file at the U. S. Agricultural Research Station, Salinas, Calif.]

[3] Lloyd, F. E. guayule (parthenium argentatum gray): a rubber plant of the chihuahuan desert. Carnegie Inst. Wash., Pub. 139, 213 pp., illus. 1911. (Reprinted 1942.)

[4] Curtis, O. F., Jr. mowing (pollarding) as a possible harvest method in guayule culture. 1948. [Unpublished manuscript on file at the U. S. Agricultural Research Station, Salinas, Calif.]

[5] "The whole plant," as the phrase is used here and later in this report, means the top plus the upper 6 to 8 inches of the root system.

comparable to the whole plant in rubber concentration and quality and in suitability for milling. Under some conditions more than 90 percent of clipped plants survived and resumed growth. Similar results were obtained by Tingey.[6]

Traub [7] showed that rubber once formed in the guayule plant is not catabolized. Therefore, the rubber left in the roots at clipping is not lost unless the plant dies, and the root rubber can be harvested later from those plants that survive. If plants do not survive clipping, the roots soon decay and the rubber they contain is lost. Since about a fourth to a third of the available rubber in a guayule plant is contained in the upper 6 to 8 inches of the root system, death of the roots of 20 percent of the plants, for example, results in loss of about 5 to 7 percent of the total rubber that was available at clipping.

The Federal program of agronomic research on guayule was resumed in 1948. Four field experiments were conducted (1) to study the survival of guayule grown with and without irrigation and fertilizer treatments and clipped at various seasons of the year, (2) to make comparisons as to shrub and rubber production between clipped and unclipped guayule grown on nonirrigated dry land, (3) to compare clipped, reclipped, and unclipped—including replanted [8]—guayule with regard to shrub and rubber production under different irrigation and fertilizer treatments, and (4) to determine the survival of two different varieties of guayule after clipping. Clipping was used as the method of final harvest in three additional experiments established in 1948–50 to study stand density, planting method, fertilizer treatment, irrigation, and variety as factors in rubber production by guayule, and observations were made on effects of differences in these factors on survival after clipping.

Of the 7 experiments, 6 were conducted near Salinas, Calif., in the principal United States area considered suitable for guayule culture, and 1 at Dilley, Tex., on the Rio Grande plains. Plants were clipped by hand in some of the experiments and with a mowing machine in the others. In sampling, plants were taken only if they were growing at 100-percent stand density.

OBJECTIVES AND PROCEDURE

Experiment 3

Experiment 3 was designed to determine the effects of irrigation and fertilizer treatments and of season of clipping upon survival of clipped guayule. It was established in March 1948 on 2.1 acres of 7-year-old shrub, spaced 36 x 24 inches, that had been grown without irrigation or fertilizer and had, on an average, 85 percent of full stand density. A split-split-plot design was used in which 3 irrigation, 4 fertilizer, and 5 clipping-date treatments were factorially combined. Irrigation, fertilizer, and clipping plots were of sizes decreasing in that order. Treatments were replicated four times.

[6] Tingey, D. C. THE EFFECT OF SPACING ON THE COMPARATIVE PRODUCTION OF RUBBER IN GUAYULE FROM PARTIAL AND COMPLETE HARVESTING. [Unpublished manuscript on file at the U. S. Agricultural Research Station, Salinas, Calif.]

[7] Traub, H. P. CONCERNING THE FUNCTION OF RUBBER HYDROCARBON (CAOUTCHOUC) IN THE GUAYULE PLANT, PARTHENIUM ARGENTATUM A. GRAY. Plant Physiol. 21: 425–444. 1946.

[8] The term "replanted" is applied to guayule stock used in reestablishing a stand on an area where guayule has been harvested by digging.

Irrigation treatments, in 1948, were as follows: Dry, none (rainfall between May 1 and August 30 averaged 0.93 inch); medium, irrigation when moisture tension at the 12-inch depth in the row reached approximately 15 atmospheres as indicated by a Bouyoucos and Mick block resistance[9] of 100,000 ohms (3 irrigations); and wet, irrigation to maintain moisture tensions at the 6-inch depth in the row below 0.85 atmosphere, as measured by soil-moisture tensiometers (4 irrigations).

Fertilizer variables were established in June 1948 by leaving check plots untreated (F_1) and making these per-acre applications: F_2, 50 pounds N (N); F_3, 150 pounds P_2O_5 (P); F_4, 50 pounds N, 150 pounds P_2O_5, and 50 pounds K_2O (NPK).

Plants were clipped at 5 dates: (1) March 1948, after 7 years of growth without irrigation or fertilizer; (2) September 1948, after a summer of differential treatment and near the end of the growing season; (3) December 1948, at the beginning of dormancy; (4) March 1949, at the end of dormancy and the beginning of spring growth; and (5) May 1949, when new growth had presumably used up a large part of the stored reserve of the plants. At each of these dates the plants on the 24 plant spaces on 1 plot in each replication were clipped about 2 inches above the crown. At the March 1948 clipping date, the plants on one plot were harvested whole by digging.

Tops clipped and whole-plant samples harvested by digging in March 1948 were analyzed for rubber content. Plants that survived and resumed growth, putting forth new shoots from the stump, were counted at intervals after clipping.

Experiment 4

The objective of experiment 4 was to determine the survival of nonirrigated guayule after clipping and to compare clipped and unclipped nonirrigated guayule with regard to yield of shrub and rubber. Clipping was the only variable. This experiment was established in March 1948 on 1.6 acres of 6-year-old nonirrigated shrub, spaced 36 x 24 inches and having 90 percent of full stand density. Four pairs of plots were established, each pair including a plot on which the guayule was clipped about 2 inches above the crown and one on which it was left undisturbed. Plots were subdivided to allow for annual sampling for determination of yield and rubber concentration. From 1949, a year after the clipping, through 1952, roots and tops of previously undisturbed shrub and of clipped shrub were taken annually from random subdivisions of each pair of plots. The point at which roots and tops were separated was normal clipping height.

Experiment 6

Experiment 6 was designed primarily to determine shrub production and rubber accumulation in clipped, reclipped, and unclipped (including replanted) guayule under different treatments with regard to irrigation and fertilizer. It was established in March 1949 on 2.6 acres of 5-year-old shrub, spaced 28 x 24 inches, that had been grown without irrigation or fertilizer and had 92 percent of full stand density. Use was made of a split-split-split-plot design in which were combined

[9] Bouyoucos, G. J., and Mick, A. H. AN ELECTRICAL RESISTANCE METHOD FOR THE CONTINUOUS MEASUREMENT OF SOIL MOISTURE UNDER FIELD CONDITIONS. Mich. Agr. Expt. Sta. Tech. Bul. 172, 38 pp., illus. 1940.

5 plant treatments, 2 irrigation treatments, and 2 fertilizer treatments. Irrigation, fertilizer, clipping, and reclipping plots were established in sizes decreasing in that order. There were 4 randomized replications of all combinations of treatments.

Plant treatments were as follows: T_1, undisturbed shrub, aged 5 years at the beginning of the experiment, harvested at all sampling dates by being dug whole; T_2, 5-year-old shrub clipped about 2 inches above the crown in March 1949, new tops within 1 plot subdivision reclipped on a 2-year cycle, new tops and old roots harvested by digging after 1, 2, 3, and 4 years; T_3, 6-year-old shrub clipped in February 1950, new tops and old roots harvested by digging after 1, 2, and 3 years; T_4, 5-year-old shrub harvested by digging in March 1949, stand immediately reestablished at the same spacing by transplanting 1-year-old nursery stock, and transplants harvested by digging after 1, 2, 3, and 4 years; T_5, same as T_4 except begun in February 1950 on plants 6 years old.

Half the plots received no irrigation. The others were irrigated in 1949 when the moisture tension at the 9-inch depth in plots of fertilized undisturbed shrub reached 15 atmospheres (indicated by Bouyoucos and Mick block resistances of 100,000 ohms), and in 1950–52 at approximately 6-week intervals during the growing season.

A fertilizer variable was established in April 1949; half the plots received no fertilizer, and half received 10–10–5 fertilizer applied at the rate of 750 pounds per acre. Fertilizer was applied only in 1949.

Plots of this experiment were sampled in February or March each year through 1953. At each date, 10-plant samples were taken from an area, within each plot, that had full stand density.

Experiment 20 [10]

The purpose of experiment 20 was to determine the survival of two different varieties of guayule after clipping at various times of year on the Rio Grande plains, in south Texas. Guayule of varieties 593 and 4265 was established in February 1949 by transplanting nursery stock to 4 randomized blocks with a total area of 0.9 acre, in 36- x 18-inch spacing. Guayule on plot subdivisions was clipped at 5 dates between October 1950 and April 1951, after 2 summers of growth in the field.

Other Experiments

The plants of experiments 5, 7, and 22, established for other purposes, were clipped by machine mowing when the experiments were terminated, in order to obtain additional information on guayule's survival and resumption of growth after clipping as affected by prior irrigation and fertilizer treatments, variations in stand density, and differences in variety.

Experiment 5 was established for the purpose of studying the effects of irrigation, fertilizer, and stand variables on rubber production by direct-seeded guayule. Guayule of variety 593 was seeded on 6.5 acres in June 1948. Factorial combinations of 6 spacing, 3 irrigation, and 2 fertilizer treatments were replicated 5 times in a split-split-plot design. Spacings, obtained by thinning, were 28 x 20 inches, 28 x 10 inches, 28 x 5 inches, 28 inches x unthinned (10 to 20 plants per lineal

[10] Conducted at Dilley, Tex., by F. A. Frank, associate agronomist, Agricultural Research Administration, in cooperation with the authors.

foot), 14 x 5 inches, and 14 inches x unthinned. Irrigation variations were dry, no irrigation; medium, irrigation at approximately 6-week intervals during the growing season; and medium wet, irrigation at approximately 4-week intervals. Half the plots received no fertilizer; half received 10–10–5 fertilizer applied at the rate of 750 pounds per acre in the spring of 1949 and in the spring of 1951. In March 1953 certain plots of this experiment were clipped by mowing; counts of plants actively growing were made in June 1953.

Experiment 7 was established in March 1949 by transplanting nursery stock of guayule varieties 593 and 4265 at the spacings 28 x 6 and 28 x 12 inches in factorial combinations. The objective was to compare the two varieties with regard to rubber production. There were 4 replications, occupying a total of 1.5 acres. The crop was irrigated at approximately 6-week intervals through the growing seasons of 1949 and 1950. All plots were clipped by mowing in the spring of 1952, and final survival counts were made in the spring of 1953.

Experiment 22 was established by transplanting nursery stock in the summer of 1950, for the purpose of comparing 3 guayule varieties and 4 guayule-stramonium hybrids (guayule variety 593 × *Parthenium stramonium*) with regard to rubber production at the spacings 28 x 10 and 28 x 20 inches. There were six replications. Uniform irrigations were made at approximately 6-week intervals during each growing season. Plants were clipped by mowing in March 1953, and final survival counts were made in September 1953.

RESULTS

Effect of Time of Clipping on Survival of Guayule

The factor found in these experiments to have the most important effect upon the ability of clipped guayule to survive and resume growth was time of clipping. The highest survival after clipping was usually that of plants clipped during guayule's winter period of dormancy, approximately the 4 months December–March. Data on this point were provided by experiments 3 and 20 (tables 1 and 2).

In experiment 3, at Salinas, 98 percent of the 7-year-old guayule plants grown without irrigation and clipped in March 1948 survived and resumed growth (table 1). Survival after September or December clipping varied markedly according to irrigation treatment before clipping. December clipping was followed by 82-percent survival of nonirrigated plants, but by practically no survival of plants that had received irrigation during the preceding summer. Clipping late in the growing season gave unsatisfactory results even for plants grown without irrigation; only 48 percent of such plants resumed growth after being clipped in September.

In this experiment only March clipping was followed by satisfactory survival of plants irrigated during the previous summer. When clipping was done in March 1949, near the end of the winter dormant season, survival of the clipped plants was at least 81 percent regardless of prior irrigation or fertilizer treatment. For plants that had been clipped in May, after the first flush of growth, survival was very poor on all plots.

Under dryland conditions in Texas, nearly all plants of both varieties tested survived being clipped during December, January, or February

(table 2). When clipping took place in October, the survival of variety 4265 was excellent and that of variety 593 was fair. Unsatisfactory survival of both varieties followed clipping done in April, after spring growth began.

Table 1.—*Survival, by clipping date and prior irrigation and fertilizer treatment, of guayule transplanted to the field in 1941 and clipped in 1948 or 1949*

[Experiment 3, at Salinas, Calif.]

Clipping date	Clipped plants surviving in August 1949, by treatment							
	Irrigation treatment in 1948[1]			Fertilizer treatment in 1948[2]				Mean
	Dry	Medium	Wet	Check	N	P	NPK	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1948:								
March	------	------	------	------	------	------	------	98.0
September	47.6	0.3	0	16.7	22.5	3.9	20.7	16.0
December	82.4	1.3	0	28.5	28.4	25.1	29.5	27.9
1949:								
March	89.2	81.1	85.9	87.1	83.5	88.5	82.5	85.4
May	21.7	8.8	15.1	20.9	15.0	10.8	14.0	15.2
Mean	60.2	22.9	25.3	38.3	37.4	32.1	36.7	------

[1] The irrigation procedure is described on p. 3. Means are for individual irrigation treatments in combination with all fertilizer treatments.
[2] Means are for individual fertilizer treatments in combination with all irrigation treatments.

Table 2.—*Survival under Texas conditions, by clipping date and variety, of guayule transplanted to the field in February 1949, grown without irrigation or fertilizer, and clipped in 1950 or 1951*

[Experiment 20, at Dilley, Tex.]

Clipping date	Clipped plants[1] surviving in June 1951, by variety		
	Variety 593	Variety 4265	Mean
	Percent	*Percent*	*Percent*
1950:			
October	68.8	96.9	82.8
December	96.9	100.0	98.4
1951:			
January	100.0	100.0	100.0
February	95.0	100.0	97.5
April	35.0	42.5	38.8
Mean	79.1	87.9	-------------

[1] At each clipping date, 32 to 40 plants were clipped.

The results of these experiments indicate that guayule plants that have not been irrigated the previous summer can be expected to survive clipping well if clipped during the winter dormant season.

Effects of Irrigation and Fertilizer Variables on Survival of Clipped Guayule

Soil moisture conditions during the growing season prior to clipping were found to be second in importance to time of clipping in effect on survival.

In experiment 3, in which differential irrigation treatments were applied through the growing season of 1948 to 7-year-old plants that had previously been grown without irrigation, irrigated guayule survived clipping in March 1949 reasonably well, but not quite so well as the nonirrigated (table 1). After clipping in September and December 1948, growth was resumed by 47 and 82 percent, respectively, of the nonirrigated plants but by practically none of the irrigated plants. After May 1949 clipping, survival was very poor for all categories.

In experiment 6, first clipping of 5-year-old guayule in March 1949 was followed by 99-percent survival (table 3). After 4 years during which the clipped plants were subjected to an irrigation differential and were reclipped on 1-, 2-, and 3-year cycles, survival on the irrigated plots averaged lower than that on the nonirrigated plots but was good to excellent. In a part of the same stand that was subjected to an irrigation differential during the growing season of 1949 and was first clipped in 1950, 99 percent of the nonirrigated plants survived the clipping while only 65 percent of the irrigated plants did so. Essentially, the same difference was maintained during the next 3 years,

Table 3.—*Survival of clipped and reclipped guayule by prior irrigation treatment*

[Experiment 6, at Salinas, Calif.]

Clipping treatment, in late February or early March	Clipped and reclipped plants surviving in June 1953, by irrigation treatment	
	Nonirrigated	Irrigated [1]
	Percent	*Percent*
Shrub clipped at 5 years, in 1949:		
Not reclipped	99	99
Reclipped 4 times on 1-year cycle	96	91
Reclipped twice on 2-year cycle	98	82
Reclipped once on 3-year cycle	99	95
Shrub clipped at 6 years, in 1950:		
Not reclipped	99	65
Reclipped twice on 1-year cycle	95	60
Reclipped once on 2-year cycle	95	59
Reclipped once on 3-year cycle	99	65

[1] Irrigation was started in 1949. Of the plants clipped in 1949, none had yet had any irrigation. The irrigation procedure is described on p. 4.

within which the irrigation differential was continued and these plants were reclipped on 1-, 2-, and 3-year cycles. Regardless of the irrigation variable, few deaths resulted from the reclipping of guayule plants that survived the first clipping of the 5- or 6-year-old shrub.

The data obtained when the direct-seeded plants of experiment 5 were clipped by mowing likewise demonstrate the important effect of previous irrigation treatment on survival after clipping (table 4). These plants had had 5 years of differential irrigation treatment prior to clipping in March 1953. Among plants grown without irrigation, those that survived the mowing amounted, on an average, to 70 percent. On the plots irrigated at 4-week intervals during the growing season, survival averaged only 38 percent. For plants grown in spacings closer than the standard 28 x 20 inches, and therefore subjected to higher moisture stresses, survival of the nonirrigated and the frequently irrigated averaged 81 percent and 47 percent, respectively.

Table 4.—*Survival, by plant spacing and prior irrigation treatment, of 5-year-old direct-seeded guayule of variety 593 clipped (by mowing) in March 1953*

[Experiment 5, at Salinas, Calif.]

Spacing (inches)	Clipped plants surviving in June 1953, by irrigation treatment [1]			
	Dry	Medium	Medium wet	Mean
	Percent	*Percent*	*Percent*	*Percent*
28 x 20	48	52	20	40
28 x 10	86	73	34	64
14 x 5	76	71	60	69
Mean	70	65	38	----------

[1] Irrigation began in 1948, the year the guayule was seeded, and continued through the growing season of 1952. Dry=no irrigation; medium=irrigation at intervals of about 6 weeks; medium wet=irrigation at intervals of about 4 weeks.

Differences in survival associated with the fertilizer variables were not significant in experiment 6 and probably were not significant in experiment 3 (table 1).

Effect of Variety on Survival After Clipping

Survival after clipping seemed to vary slightly according to plant variety. In south Texas, variety 4265 survived hand clipping slightly better than variety 593 (table 2). Both varieties survived excellently when clipped during the winter months. It appears that in the Salinas Valley variety 593 survived clipping with a mowing machine somewhat better than variety 4265 (table 5). In the experiment involving guayule and guayule-stramonium hybrids, in which the survival of all varieties and hybrids was low, hybrid D–242 survived best and survival of the hybrids in general compared well with that of guayule (table 5).

TABLE 5.—*Survival of guayule varieties and hybrids after spring clipping (by mowing) at the age of 3 years, by spacing*

[Experiments 7 and 22, at Salinas, Calif.]

Experiment,[1] clipping date, and spacing (inches)	Clipped plants surviving[2]								
	Guayule variety				Guayule-stramonium hybrid				
	593	4265	4265 IG	4265 X	D–240	D–242	D–243	D–247	Mean
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Experiment 7, spring 1952:									
28 x 12	92	87							90
28 x 6	97	90							94
Mean	95	89							
Experiment 22, March 1953:									
28 x 20	35		21	28	23	36	24	25	27
28 x 10	55		33	29	41	64	52	52	47
Mean	45		27	29	32	50	38	39	

[1] Transplanting took place in March 1949 in experiment 7 and in the summer of 1950 in experiment 22. In experiment 7 the plots were irrigated at intervals of about 6 weeks through the growing season in 1949 and 1950; in experiment 22, the plots were thus irrigated in 1950–52.

[2] The survival counts of experiment 7 were made in the spring of 1953; those of experiment 22, in September 1953.

Effect of Plant Density on Survival After Clipping

In the experiments in which it was possible to compare results obtained with different plant densities, higher survival was associated with plant spacing closer than the standard 28 x 20 inches, regardless of irrigation treatment or of variety (tables 4 and 5). Greater density of plants, because it results in greater absorption of moisture from the soil, results in greater soil-moisture stress and longer periods of high stress and dormancy. This undoubtedly explains the advantage in survival associated with greater density. In experiment 5 the plants spaced 14 x 5 inches, which had the greatest average percentage of survival, undoubtedly were subjected to higher moisture stresses than plants grown at densities one-fourth and one-eighth as great, even though they were irrigated similarly. The additional stress due to close planting did not cause better survival after conditions of high stress induced by lack of irrigation, but it had great significance in relation to survival after low-stress conditions induced by irrigation at 4-week intervals.

Comparison of Yields Obtained by Clipping and Whole-Plant Harvesting

The yields of shrub and rubber obtained by different methods and sequences of methods of harvesting were compared in experiments 3, 4, and 6.

In experiment 3, the 7-year-old guayule that was dug to a depth of 6 to 8 inches in March 1948 yielded at the rate of 10,350 pounds of dry shrub per acre and contained 14.1 percent rubber hydrocarbon, or 1,459 pounds of rubber per acre (acre rates calculated on the basis of 100-percent stand density). The tops clipped from comparable plants gave a per-acre yield of 7,000 pounds of shrub with a rubber content of 15.2 percent, or 1,064 pounds. The rubber harvested by clipping amounted, therefore, to more than 72 percent of the rubber in the whole plants. Of the plants clipped in March 1948, before differential irrigation and fertilizer treatment began, only 2 percent failed to survive and resume growth (table 1); the rubber lost in roots of these plants that died as a result of clipping totaled about 0.6 percent of that available for harvest, or about 8 pounds per acre.

In experiment 4, which was established on plants 6 years old and in which plants were never irrigated, 99 percent of the plants survived clipping. Data from five harvests of unclipped and clipped plants are presented in table 6. At the first clipping, in 1948, a per-acre yield of 5,065 pounds of shrub and 880 pounds of rubber was harvested in the plant tops removed. On an average, unclipped plants harvested in 1948 yielded at the per-acre rate of 6,950 pounds of shrub containing 1,174 pounds of rubber. Of the rubber present in the whole plants, 75 percent was harvested in the clipped tops. Only about 3 pounds of rubber per acre was lost in the roots of the 1 percent of the clipped plants that died.

During the first year of the experiment, unclipped plants gained at the rate of 675 pounds of shrub and 90 pounds of rubber per acre and clipped plants gained at the rate of 3,420 pounds of shrub and 475 pounds of rubber per acre. For the unclipped plants, no increases in

yield of shrub and no significant increases in yield of rubber were shown after 1950, probably owing in part to loss of branches as a result of unavoidable mechanical damage in cultivation. Gains in yield of shrub and rubber were shown by the clipped plants throughout the experiment. At each harvest after the first, the clipped plants had produced more rubber than the unclipped plants; the differences were significant in 1951 and 1952. The concentration of rubber in the new tops on old roots increased from 11.2 percent in the second year to 14.1 percent in the fourth year; the concentration in the unclipped plants remained essentially constant at about 16.5 percent from 1948 to 1951 but increased somewhat in 1952.

Table 7 summarizes, for experiment 6, the yields of shrub and rubber and the concentration of rubber obtained through each of several methods and combinations of methods of harvesting guayule, including clipping, reclipping, and digging. This experiment provides comparative production figures for unclipped 5- to 9-year-old plants, new tops produced on old roots after clipping at 5 or 6 years of age, plants clipped at 5 or 6 or at 5 and 7 years of age and harvested by digging at various ages, and nursery stock transplanted to land on which 5- and 6-year-old shrub had been harvested by digging.

Although the rubber yield is of primary concern, the bulk of shrub produced and the concentration of rubber are of interest because they directly affect the economics of handling the shrub and processing it for rubber. In this experiment, significant differences in shrub yield and rubber concentration between irrigated and nonirrigated plots were found for all treatments at all harvest dates after irrigation began. Yields of shrub were higher and concentrations of rubber were lower for irrigated than for nonirrigated plots, with the net result that differences in yield of rubber were not significant. Under Salinas Valley conditions, at the plant spacing used in this experiment, irrigation was not profitable.

Yields of shrub did not vary significantly according to fertilizer treatment (which was applied only once, in 1949). Therefore, data from fertilized and unfertilized plants are composited in table 7.

When experiment 6 was begun, in 1949, the plants, which had grown in the field for 5 years without irrigation, fertilizer, or clipping, had a whole-shrub weight of 6,980 pounds per acre, contained 14.4 percent rubber, and yielded rubber at the rate of 1,003 pounds per acre. By clipping the tops, per-acre yields of 4,720 pounds of shrub and 686 pounds of rubber were obtained. The rubber harvested by clipping amounted to 68 percent of the total available. At the 1950 clipping of 6-year-old shrub, about 75 percent of the available rubber was harvested in the tops.

At the 1950 harvest, the greatest cumulative total per-acre yield of shrub and of rubber was obtained by digging plants clipped a year earlier. The next greatest yield was from digging of unclipped plants, which during their sixth year in the field had gained rubber at the rate of 250 pounds per acre. The third highest cumulative rubber yield was from the digging of shrub in 1949 and the digging at 1 year of the transplants that replaced it; however, the transplants gave a very low yield of rubber after 1 year in the field—on an average, 50 pounds per acre. Clipping of tops only showed a 1-year gain in rubber yield at the rate of 244 pounds per acre.

TABLE 6.—*Shrub yield, rubber concentration, and rubber yield of guayule transplanted to the field in 1943, grown without irrigation, clipped in March 1948, and later harvested by digging, and of unclipped guayule otherwise having the same history*

[Experiment 4, Salinas, Calif.]

YIELD OF SHRUB (DRY WEIGHT)

Material harvested	Average, by date of harvest				
	March 1948	March 1949	February 1950	February 1951	June 1952
	Pounds per acre	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
Unclipped plants:					
Tops	----	----	6, 525	6, 340	6, 280
Roots	----	----	2, 690	2, 840	2, 785
Total for individual harvest	6, 950	7, 625	9, 215	9, 180	9, 065
Difference from next previous harvest	----	+675	+1, 590	−35	−115
Clipped plants:					
Tops	5, 065	----	2, 140	2, 725	3, 775
Roots	----	----	2, 870	2, 840	3, 210
Total for individual harvest	5, 065	3, 420	5, 010	5, 565	6, 985
Total to date	5, 065	8, 485	10, 075	10, 630	12, 050
Difference from next previous harvest	----	+3, 420	+1, 590	+555	+1, 420
Difference from unclipped plants	----	+860	+860	+1, 450	+2, 985

RUBBER CONCENTRATION

Unclipped plants:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Tops			16.5	16.6	18.1
Roots			16.0	16.6	17.6
Weighted mean	16.9	16.5	16.4	16.6	18.0
Clipped plants:					
Tops	17.4		11.2	13.5	14.1
Roots			16.8	17.3	18.8
Weighted mean		13.9	15.1	15.4	16.2

YIELD OF RUBBER

Unclipped plants:	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
Tops			1,077	1,052	1,138
Roots			431	474	490
Total	1,174	1,264	1,508	1,526	1,628
Difference from next previous harvest		+90	+244	[1] +18	[1] +102
Clipped plants:					
Tops	880		275	368	530
Roots			482	490	602
Total for individual harvest	880	475	757	858	1,132
Total to date	880	1,355	1,637	1,738	2,012
Difference from next previous harvest		+475	+282	+101	+274
Difference from unclipped plants		[1] +91	[1] +129	+212	[2] +384

[1] Difference nonsignificant. [2] Difference highly significant.

TABLE 7.—*Shrub yield, rubber concentration, and rubber yield of guayule grown with and without irrigation and harvested by several methods including clipping, reclipping, and digging*

[Experiment 6, at Salinas, Calif.]

Time of harvest and treatment number	Material harvested and method of harvesting	Age at harvest [1]		Yield of shrub [2]				Concentration of rubber in shrub harvested		Yield of rubber				
				At harvest		Cumulative total at harvest				At harvest		Cumulative total at harvest		
		Tops	Roots	Dry plots	Irrigated plots	Dry plots	Irrigated plots	Dry plots	Irrigated plots	Dry plots	Irrigated plots	Dry plots	Irrigated plots	Mean
		Yr.	*Yr.*	*Lb. per acre*	*Lb. per acre*	*Lb. per acre*	*Lb. per acre*	*Pct.*	*Pct.*	*Lb. per acre*	*Lb. per acre*	*Lb. per acre*	*Lb. per acre*	*Lb. per acre*
March 1949:														
1,4	Unclipped shrub, dug	5	5	6, 980	------	6, 980	------	14. 4	-----	1, 003	-----	1, 003	-----	1, 003
2	Tops only, clipped	5	5	4, 720	------	4, 720	------	14. 7	-----	686	-----	686	-----	686
February 1950:														
1,5	Unclipped shrub, dug	6	6	8, 240	10, 840	8, 240	10, 840	14. 8	12. 1	1, 210	1, 297	1, 210	1, 297	1, 253
2	Second tops, old roots, dug	1	6	4, 660	7, 040	9, 380	11, 760	12. 5	9. 9	580	696	1, 266	1, 382	1, 324
3	Tops only, clipped	6	6	6, 100	8, 100	6, 100	8, 100	15. 2	11. 6	923	937	923	937	930
4	Transplants, set 1949, dug	1	1	330	1, 100	7, 310	8, 080	9. 0	6. 4	30	71	1, 033	1, 074	1, 054
February 1951:														
1	Unclipped shrub, dug	7	7	9, 400	11, 000	9, 400	11, 000	15. 1	12. 7	1, 410	1, 392	1, 410	1, 392	1, 401
2	Second tops only, clipped	2	7	2, 740	4, 740	7, 460	9, 460	11. 2	8. 4	308	399	986	1, 085	1, 040
2	Second tops, old roots, dug	2	7	6, 020	9, 320	10, 740	14, 040	13. 5	10. 9	812	975	1, 498	1, 661	1, 590
3	Second tops, old roots, dug	1	7	2, 320	3, 200	8, 420	11, 300	13. 1	11. 0	642	673	1, 565	1, 610	1, 588
4	Transplants, set 1949, dug	2	2	1, 580	3, 620	8, 560	10, 600	8. 1	7. 0	228	256	1, 231	1, 259	1, 245
5	Transplants, set 1950, dug	1	1	480	860	8, 720	11, 700	7. 0	5. 3	34	46	1, 244	1, 343	1, 294
	L. S. D. (P=0.05)	-----	-----	------	------	------	------	-----	-----	-----	-----	-----	-----	96

February 1952:														
1	Unclipped shrub, dug	8	8	10, 020	12, 440	10, 020	12, 440	16. 7	13. 1	1, 690	1, 625	1, 690	1, 625	1, 658
2	Second tops, old roots, dug	3	8	8, 100	10, 180	12, 820	14, 900	15. 3	11. 4	1, 238	1, 170	1, 924	1, 856	1, 890
3	Second tops, old roots, dug	2	8	6, 100	8, 400	12, 200	16, 500	14. 9	11. 1	908	935	1, 831	1, 872	1, 852
4	Transplants, set 1949, dug	3	3	4, 000	6, 000	10, 980	12, 980	11. 7	8. 5	470	515	1, 473	1, 518	1, 496
5	Transplants, set 1950, dug	2	2	2, 520	3, 860	10, 760	14, 700	10. 2	6. 9	256	265	1, 466	1, 562	1, 514
	L. S. D. (P=0.05)													141
February 1953:														
1	Unclipped shrub, dug	9	9	11, 880	12, 240	11, 880	12, 240	15. 6	12. 6	1, 855	1, 540	1, 855	1, 540	1, 698
2	Second tops, old roots, dug	4	9	9, 960	11, 920	14, 680	16, 640	14. 3	10. 7	1, 419	1, 276	2, 105	1, 962	2, 034
2	Third tops, old roots, dug	2	9	7, 060	9, 080	14, 520	18, 540	14. 2	11. 4	999	1, 031	1, 985	2, 116	2, 055
3	Second tops, old roots, dug	3	9	8, 300	10, 820	14, 400	18, 920	14. 2	11. 2	1, 182	1, 216	2, 105	2, 153	2, 129
4	Transplants, set 1949, dug	4	4	5, 500	7, 100	12, 480	14, 080	13. 1	9. 5	723	673	1, 726	1, 676	1, 701
5	Transplants, set 1950, dug	3	3	4, 180	5, 180	12, 420	16, 020	11. 9	9. 3	497	484	1, 707	1, 781	1, 744
	L. S. D. (P=0.05)													196

[1] Counted from date of transplanting to field.
[2] Dry and defoliated.

At the harvest in 1951, completely harvesting the 2-year-old new tops and 7-year roots of plants clipped in 1949 resulted in practically the same cumulative yield of rubber as completely harvesting the 1-year new tops and 7-year roots of plants clipped in 1950. The mean per-acre rubber yield for each of these combinations was about 190 pounds greater than that of 7-year-old unclipped shrub, about 345 pounds greater than that of the combination of 5-year-old unclipped shrub dug in 1949 and 2-year-old transplants, and about 295 pounds greater than that of 6-year-old shrub dug in 1950 plus 1-year-old transplants. The rubber yield of the unclipped shrub increased at the rate of approximately 150 pounds per acre between the 1950 and 1951 harvests. All these differences were significant.

In 1952, harvest of 3-year new tops and 8-year roots from which the first tops had been clipped in 1949 and harvest of 2-year tops and 8-year roots from which the first tops had been clipped in 1950 gave cumulative per-acre rubber yields significantly higher than those of any other plants harvested, 1,890 pounds and 1,852 pounds, respectively. These yields exceeded by 300 pounds and 264 pounds, respectively, those of shrub clipped in 1949 and 1950 and dug in 1951. During the year preceding the 1952 harvest the cumulative rubber yield of unclipped shrub harvested by digging in 1949 and 1950 plus transplants set in those years had increased at the per-acre rates of 251 pounds and 220 pounds.

At the final harvest in 1953, essentially similar cumulative rubber yields resulted from the harvest of 9-year roots and 4-year tops of plants first clipped in 1949, 9-year roots and 2-year tops of plants first reclipped in 1951, and 9-year roots and 3-year tops of plants first clipped in 1950; for each of these sequences, the rubber yield per acre exceeded a ton. Significantly smaller per-acre yields of 1,698 to 1,744 pounds were given by the three other sequences. Between the 1952 and 1953 harvests there had been very little increase in rubber content of the whole shrub.

Plants clipped after 5 or 6 years in the field and harvested by digging 2, 3, or 4 years later produced significantly greater cumulative yields of rubber than plants grown for 7, 8, or 9 years without clipping and then dug. Furthermore, at each harvest the plants to which each of these clipping treatments had been given yielded significantly more rubber than unclipped plants dug at 5 or 6 years plus transplants dug at 1, 2, 3, or 4 years. Also, at any harvest there was no significant difference between the rubber yield of unclipped plants 7, 8, or 9 years old and that of 5-year plants plus 1-, 2-, 3-, or 4-year transplants or 6-year plants plus 1-, 2-, or 3-year transplants. The total rubber yields produced during an 8-year or 9-year period under clipping procedures were similar regardless of whether the original harvest had taken place when the plants were 5 years or 6 years old, and the same thing was true of yields produced under replanting procedures. On the basis of 100-percent stand density, the unclipped shrub made increases in rubber yield per acre averaging about 215 pounds annually between the ages 5 and 8 years; in the ninth year, the increase was only 40 pounds.

DISCUSSION

For any sequence of clipping and digging to prove superior to digging alone as a method of harvesting guayule, a high percentage of the clipped plants must survive the clipping operation and the chosen

sequence must, within a given period, produce more rubber or produce rubber at a lower cost per pound than either one digging or a replanting sequence including two diggings would produce within the same period.

In general, survival of clipped plants was higher if clipping had taken place in February or March. These months are the season of greatest concentration of rubber in guayule. Clipping at this season, therefore, would not only involve minimum loss of stand but also permit highest yield of rubber.

It seems probable that deficiencies in food reserves were responsible for the failure of irrigated plants at Salinas to survive clipping in September or December. Under Salinas Valley conditions irrigated plants were still growing in September and had been dormant for only a short time when clipped in December. Plants grown without irrigation, on the other hand, were forced into dormancy in July through exhaustion of available moisture and had been dormant for several weeks when clipped in September.

Guayule grown at Salinas demonstrated its ability to survive satisfactorily repeated clippings at intervals as short as 1 or 2 years.

The yields reported here are larger than could be obtained on a field scale. Although plants were taken in sampling only if they were growing at 100-percent stand density, the stands present on the experimental areas had densities averaging not greater than 85 to 95 percent under the best conditions.

Since harvesting of guayule by clipping has been experimental only, no data are available on the actual relative costs of producing guayule rubber by the methods and combinations of methods tested in these experiments. Some conclusions may be drawn, however, from a general knowledge of the operations involved. A single harvest of plants by digging after 8 or 9 years in the field would be less expensive than any combination of two harvest methods and would also entail less loss of plants than any harvesting system that involves clipping. On the other hand, greater quantities of rubber are produced per acre by clipping plus subsequent harvest of new tops and old roots by digging, under perfect-stand conditions and conditions favoring high survival of clipped plants. Under other conditions, the economic advantages of a single harvest in comparison with two harvests including a clipping depend upon the extra costs of handling the greater volume of shrub from clipped plants, the costs of the additional harvesting operation, and the price of rubber. In 1953, the cumulative total rubber yields from irrigated and nonirrigated plants that were dug 4 years after being clipped were 336 and 250 pounds per acre greater, respectively, than that obtained by digging of comparable unclipped plants; these values represent yield advantages of 20 and 12 percent.

Harvesting unclipped plants by digging, replacing them with transplants, and subsequently digging the transplants would make rubber production cost more per acre than either of the two other methods discussed, owing to the costs of producing nursery stock, preparing land to receive it, and transplanting it and the costs of cultivation and weed control in new plantings. Further, the cumulative rubber yields were in all cases less than the comparable cumulative yields from roots and first and second tops of clipped plants and, until the replants reached an age of 3 years, were less than the yields from digging unclipped shrub.

SUMMARY

In seven field experiments, clipping was tested as a method of harvesting guayule that would leave the plant alive for further production of rubber. Of these experiments, 6 were conducted at Salinas, Calif., and 1 at Dilley, in south Texas. Plants were clipped about 2 inches above the crowns, either by hand or with a mowing machine. Research objectives included (1) comparing the amounts of shrub and rubber obtained by clipping with those obtained in harvest by the customary method of digging to a depth of 6 to 8 inches; (2) determining the effects of time of clipping, previous irrigation and fertilizer treatments, guayule variety, and stand density on the ability of the plants to survive clipping; and (3) comparing the rubber concentration and total yield of shrub and of rubber obtained through (a) harvest by digging, (b) partial harvest by clipping and subsequent harvest by digging, and (c) harvest by digging followed by replanting and harvest of the new stand 1 to 4 years later.

The rubber obtained by clipping tops of 5- to 7-year-old guayule amounted to from 68 to 75 percent of all the rubber the plants contained.

The factor that had the most important effect on the ability of guayule to survive clipping was time of clipping. In general, good to excellent survival followed clipping of nonirrigated guayule during the 4 months December–March (normally the dormant season). In Texas, excellent survival of a planting of variety 4265 and fair survival of a planting of variety 593 followed October clipping; aside from this, plants clipped during the growing season survived poorly or very poorly.

Irrigation treatment during the growing season prior to clipping ranked second to time of clipping as a factor in survival. Regardless of when they were clipped, nonirrigated plants survived clipping in greater percentages than irrigated plants. No significant differences in survival were associated with fertilizer variables. Higher survival was associated with plant spacings closer than 28 x 20 inches. Survival after clipping seemed to be affected only slightly by variety; in south Texas variety 4265 apparently survived better than variety 593, and in the Salinas Valley the advantage seemed to be reversed.

Cumulative yields of rubber from plants partially harvested by clipping after 5 or 6 years in the field and completely harvested by digging 1, 2, 3, or 4 years later were, in all cases, greater than the yields from unclipped plants of the same age. Complete harvest of 5- or 6-year-old plants, immediate replacement with transplants, and complete harvest of the transplants 1 to 4 years later resulted in cumulative total rubber yields somewhat less than the yields of unclipped plants of an age equal to the sum of the ages of the two crops.

Shrub yield was increased and rubber concentration was decreased by irrigation, with the net result that rubber production by irrigated guayule did not differ significantly from that by nonirrigated guayule.

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